Charge Transport in High-Energy Hadron Collisions

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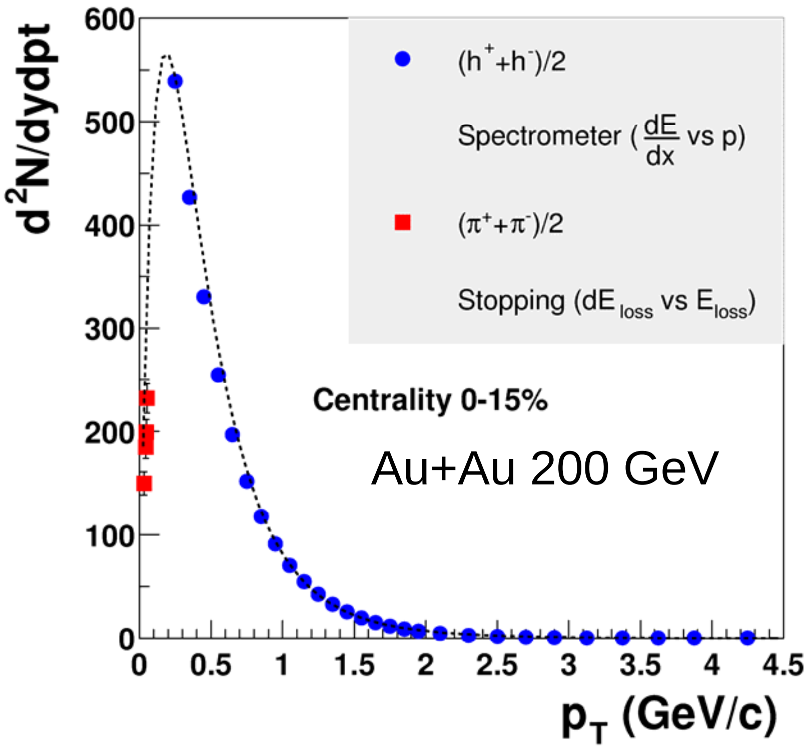
PANIC 05

The most interesting question at RHIC (IMHO)



PHOBOS, Nucl. Phys. A 757, 28

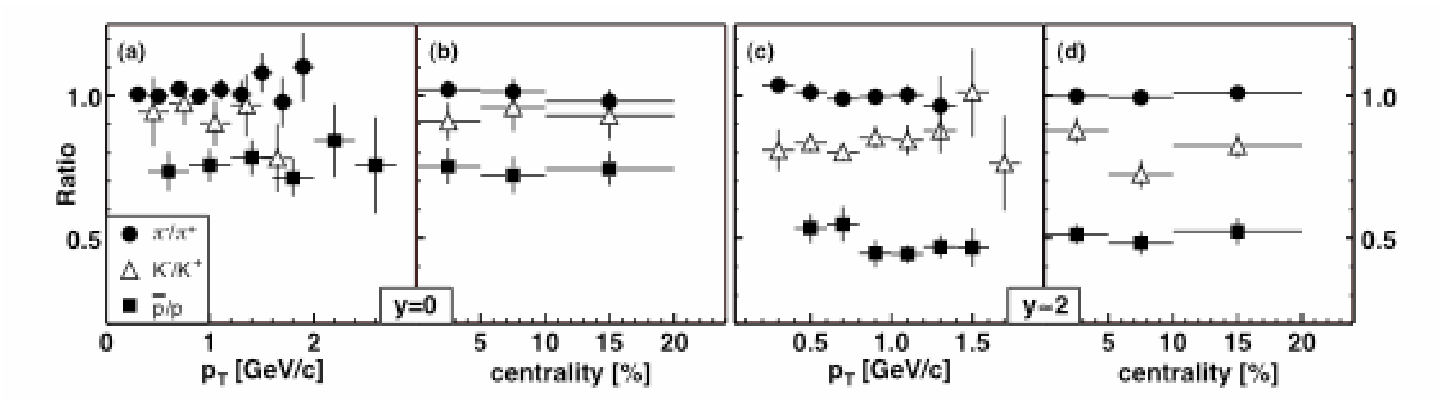
Allowing that "the bulk" of hadrons produced in a RHIC A+A collision are from the decay of an extended QGP, then:

How does "the bulk" form?

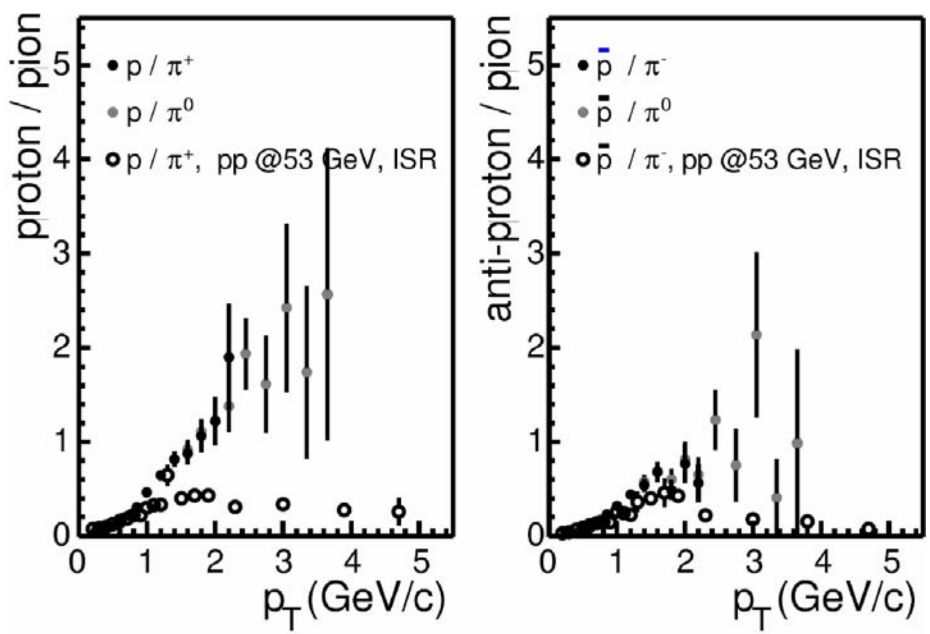
→Initial transport?

→Initial thermalization?

Transport of conserved quantities



BRAHMS, Phys Rev Lett 90, 102301 (2003)



PHENIX, Phys. Rev. C 69, 024904 (2004)

Example: Baryon number

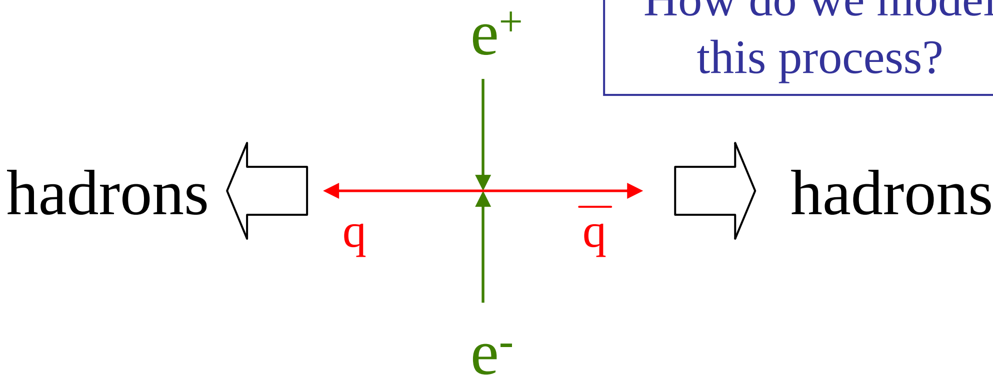
How does it get to mid-rapidity?

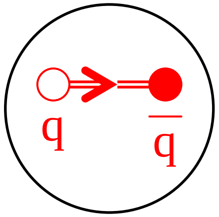
How does it get to high p_T?

Cannot be treated easily in pQCD!

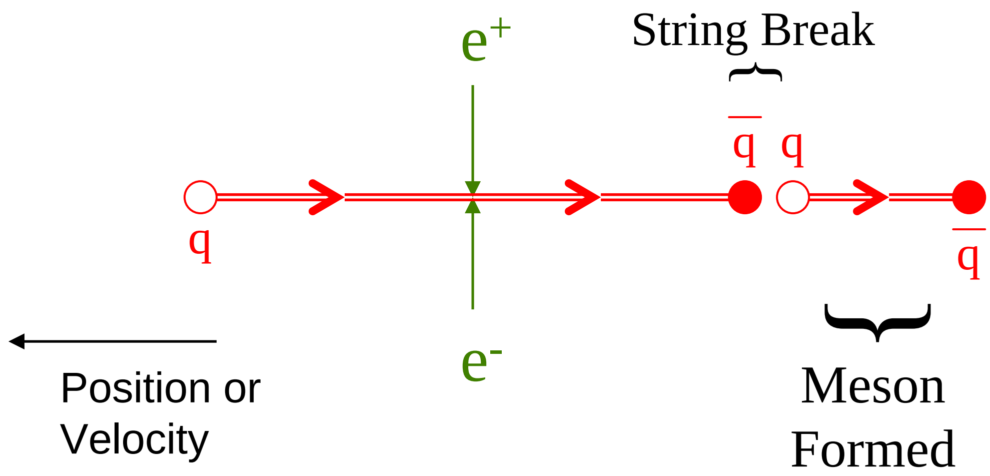
Low-brow review of color strings

How do we model this process?

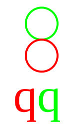




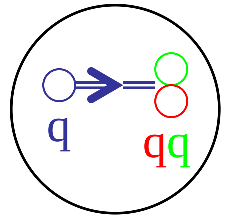
Model of a meson



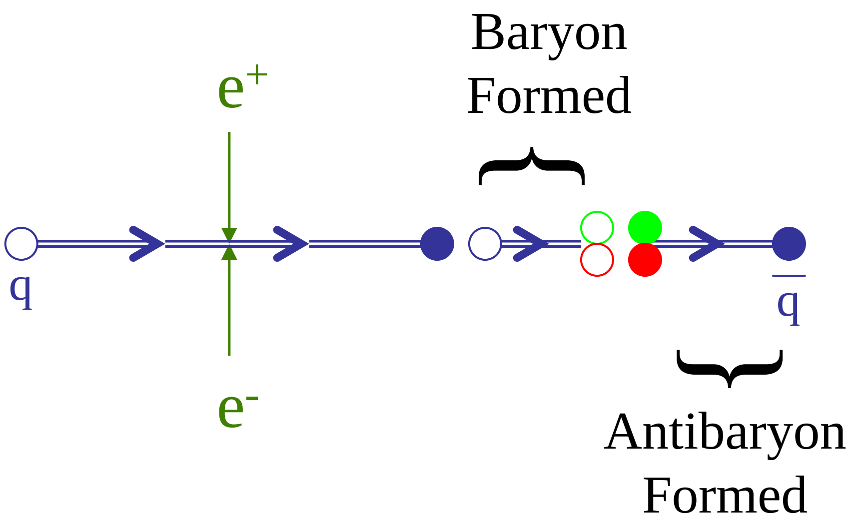
Extension to baryons

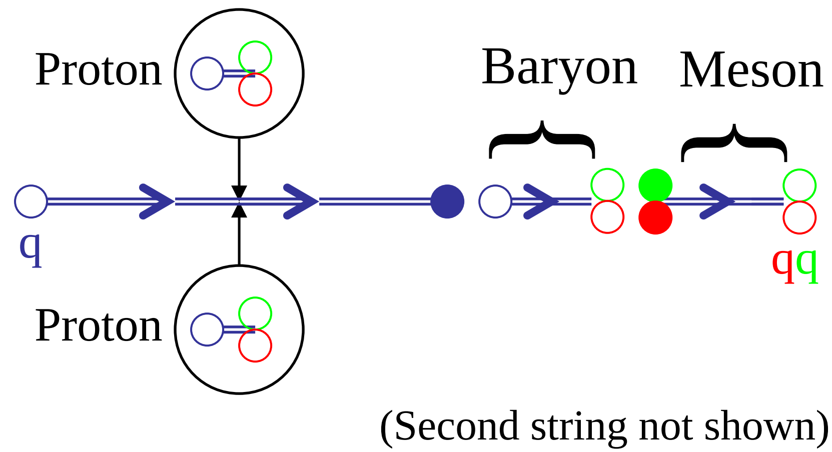


Enter the Diquark, an anti-colored object
(in this case, red+green = anti-blue)



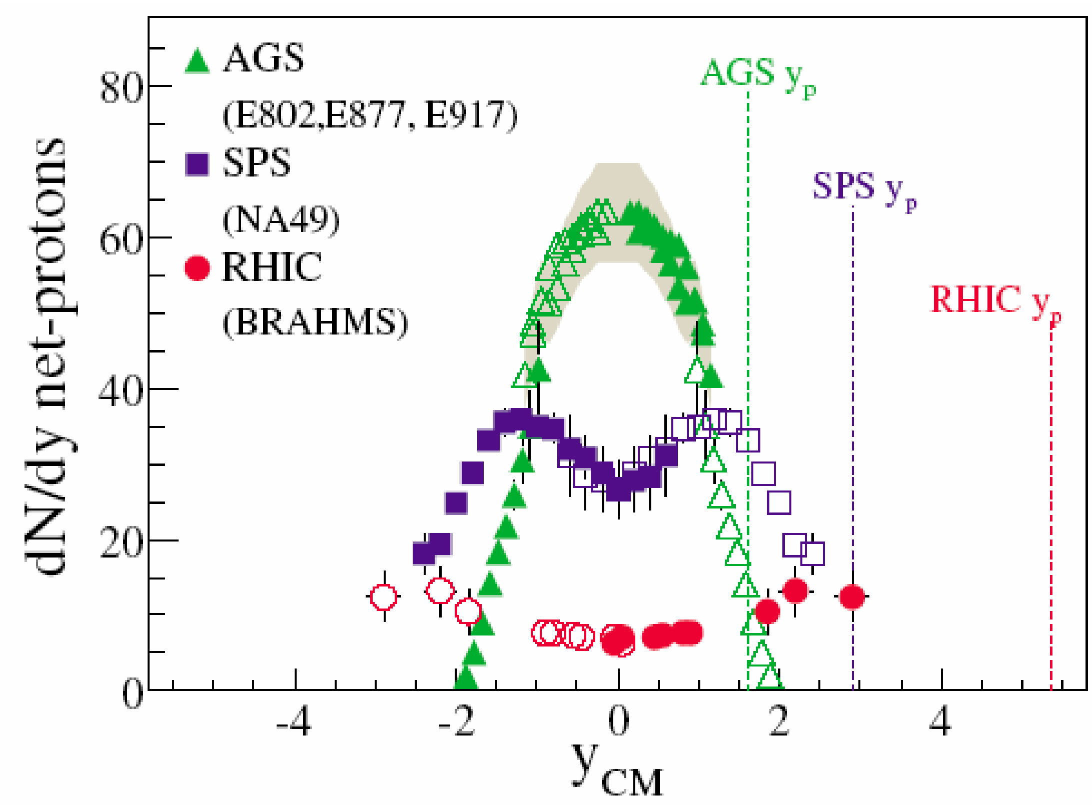
Model of a Baryon

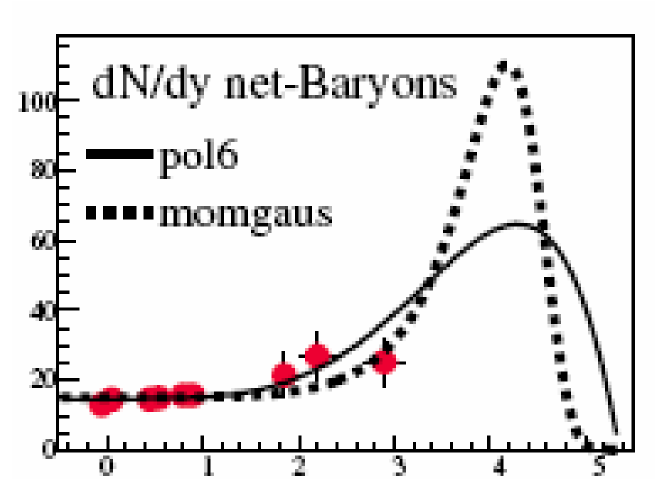




Baryon transport combinatoric!

Too many baryons?



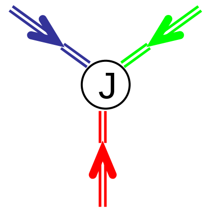


Exponential transport *not* observed!

BRAHMS Phys Rev Lett 93 102301 (2004)

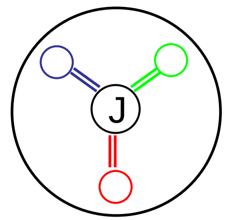
Enter the Junction

Montanet, Rossi, Veneziano, *Phys Rept.* 63 (1980)
Kharzeev, *Phys Lett* **B**378 (1996)

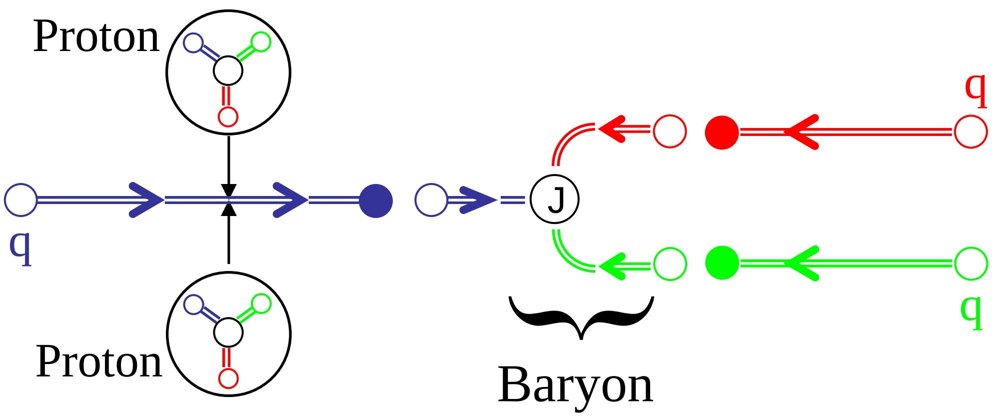


The **Junction:**

A legal QCD object
Gluon fields
Electrically neutral



New Model of a Baryon



Baryon number transported *separately* from quarks

What's the big idea?

We can measure baryon transport and charge transport *independently* and distinguish between different mechanisms:

$$\text{If}\quad \frac{dN^{B}}{dY} - \frac{dN^{\bar{B}}}{dY} = \frac{\text{Net}}{\text{Baryons}} \neq 0 \quad \text{then test:}$$

$$\frac{\text{Net}}{\text{Charge}} \quad \frac{dN^{(+)}}{dY} - \frac{dN^{(-)}}{dY} = 0$$

Pure junction stopping

$$\frac{\text{Net}}{\text{Charge}} \quad \frac{dN^{(+)}}{dY} - \frac{dN^{(-)}}{dY} = \frac{Z_{\text{Beam}}}{A_{\text{Beam}}}\left(\frac{dN^{B}}{dY} - \frac{dN^{\bar{B}}}{dY}\right)$$

Pure quark stopping

A simple plan

Assume: All charge in $\pi^{\pm}$, $K^{\pm}$, $\boldsymbol{p}$, $\boldsymbol{p}$bar

All baryon number in $\boldsymbol{p}$, $\boldsymbol{n}$, Λ

Notation: "π^{+}" = $dN^{\pi+}/dY$

"π^{Net}" = $\pi^{+} - \pi^{-} = dN^{\pi+}/dY - dN^{\pi-}/dY$

Strategy: Examine RHIC A+A, d+A, p+p, ISR data

In *theory* look at N^{+}-$N^{-} = \pi^{Net} + K^{Net} + \boldsymbol{p}^{Net}$

In *practice* look at $(\pi^{Net}+K^{Net})/\boldsymbol{p}^{Net}$

$$\frac{\pi^{\mathrm{Net}}+K^{\mathrm{Net}}}{p^{\mathrm{Net}}}=-1.00$$

Junction stopping

Quark stopping

$$\frac{\pi^{\mathrm{Net}}+K^{\mathrm{Net}}}{p^{\mathrm{Net}}}=\frac{Z}{A}\left(\frac{n^{\mathrm{Net}}}{p^{\mathrm{Net}}}+\frac{\Lambda^{\mathrm{Net}}}{p^{\mathrm{Net}}}\right)-\left(1-\frac{Z}{A}\right)$$

$$=\frac{Z}{A}\frac{n}{p}\left(1+\frac{\bar{p}/p-\bar{n}/n}{1-\bar{p}/p}\right)+\frac{Z}{A}\frac{\Lambda}{p}\left(1+\frac{\bar{p}/p-\bar{\Lambda}/\Lambda}{1-\bar{p}/p}\right)-\left(1-\frac{Z}{A}\right)$$

$$=0.0\leftrightarrow 0.2\quad \text{for RHIC Au}+\text{Au}$$

Know $\bar{\Lambda}/\Lambda\cong\bar{p}/p$ Presume $\bar{n}/n\cong\bar{p}/p$

Know $\Lambda/p\cong 0.5$ Presume $n/p=\left[1\leftrightarrow(A-Z)/Z=1.5\right]$

$$\frac{\pi^{\mathrm{Net}}+K^{\mathrm{Net}}}{p^{\mathrm{Net}}}=\frac{\pi^{+}(1-\pi^{-}/\pi^{+})+K^{+}(1-K^{-}/K^{+})}{p(1-\bar{p}/p)}$$

Examine RHIC central Au+Au, Y~0, 200 GeV

$$\pi^{+}=290 \quad K^{+}=47 \quad p=26 \quad \text{BRAHMS}$$

PRL 93 102301 (2004)
PRL 94 162301 (2004)

$$\bar{p}/p=0.74\pm0.03 \quad \text{various}$$

$$K^{-}/K^{+}=0.95\pm0.05 \quad \text{BRAHMS}$$

$$=0.95\pm0.042 \quad \text{PHOBOS}$$

$$=0.95\pm0.032 \quad \text{combined}$$

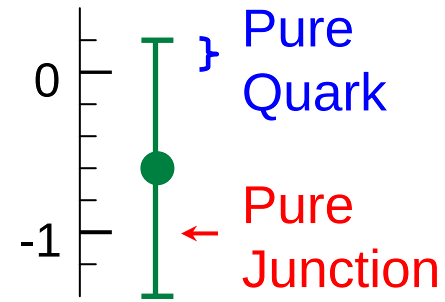
PHOBOS PRC 67 021901 (2003)

BRAHMS PRL 90 102301 (2003)

$$\pi^{-}/\pi^{+}=1.01\pm0.04 \quad \text{BRAHMS}$$

$$=1.025\pm0.019 \quad \text{PHOBOS}$$

$$=1.022\pm0.017 \quad \text{combined}$$



Dominant!

$$\frac{\pi^{\mathrm{Net}}+K^{\mathrm{Net}}}{p^{\mathrm{Net}}}=\frac{290(-0.022\pm0.017)+47(0.05\pm0.032)}{26(0.26\pm0.03)}$$

$$=\frac{(-6.38\pm4.93)+(2.35\pm1.50)}{6.76\pm0.78}=-0.60\pm0.82$$

Similar conclusion for RHIC p+p and d+Au data.

Conclusions

Inconclusive! at least, with current data

p*bar/*p measures baryon stopping; ±5% precision needed

π^-/π^+ measures charge stopping; ±0.5% precision needed

Current RHIC experiments can probably achieve this….

…but how would you design a *new* precision low-p_T experiment?

Next: Fix up this calculation (include $\Sigma^\pm$, ISR data, μ_Q, etc.)

Charge transport vs p_T or Y_T

Control input charges: p+A vs n+A, or

$${}^{96}_{40}\mathrm{Zr}+{}^{96}_{40}\mathrm{Zr}$$

$${}^{96}_{44}\mathrm{Ru}+{}^{96}_{44}\mathrm{Ru}$$